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# ESTIMATION AND ANALYSIS OF CYCLE EFFICIENCY FOR SHELL AND TUBE HEAT EXCHANGER BY GENETIC ALGORITHM

**Uttam Roy**
Research Scholar, School of Hydro-informatics Engineering, National Institute of Technology, Agartala, Barjala, Jirania, Tripura West - 799046, India.

**Mrinmoy Majumder**
Assistant Professor, School of Hydro-informatics Engineering, National Institute of Technology, Agartala Barjala, Jirania, Tripura West - 799046, India

**ABSTRACT**

*Shell and tube Heat exchanger (STHE) is one of the most common and widely used energy transporter suited for domestic usages as well as industrial applications. In this paper, we consider shell and tube heat exchanger as a device with known input and output parameters. This work utilizes imperative design constraints like tube configuration, fluids, surface and temperature (constant magnitude) as input parameters and energetic cycle efficiency considered as desired output parameter depicting performance of the device. The model was trained and tested by proposed Genetic algorithm (GA) technique. This entire computational procedure is implemented in MATLAB platform.*

*The trivial objective of this work is to predict optimal energetic cycle efficiency which is one of the most significant parameter for STHE to impact overall efficiency of the plant .In this research, output results obtained from proposed method is analyzed and compared with actual dataset. It is found that 30-tube configuration is best which reduces slip-up of energetic cycle efficiency by proposed method with actual data. Errors are identified and validated with target dataset. The proposed Genetic Algorithm (GA) technique demonstrated optimal energetic cycle efficiency with target data at low cost and less time.*

**Key words:** Shell and tube Heat exchanger (STHE), Genetic algorithm (GA); Energetic cycle efficiency, MATLAB

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## 1. INTRODUCTION

Heat exchangers (HE) are devices used to transfer thermal energy between two or more fluids from a hot fluid to a cold fluid direction. [1] In a computer-based design, many thousands of alternative

exchanger configurations may be examined. Computer codes for design are organized to vary systematically the exchanger parameters such as, shell diameter, baffle spacing, number of tube-side pass to identify configurations that satisfy the specified heat transfer and pressure drops.[2] Heat exchangers have wide range of applications from heating and air conditioning systems in a household, to chemical processing and power production in a large plant.[3 ] The shell-and tube exchangers, is most common type of heat exchangers are the automobile radiators, condensers, evaporators, air pre heaters, and cooling towers.[4] STHE has wide usability, but best suited for high pressure and high temperature applications. They also widely used in refrigeration, power generation, heating and air conditioning, chemical processes, manufacturing, and medical applications.[5] In this paper, the heat transfer coefficient and pressure drop on the shell side of a shell-and-tube heat exchanger have been experimentally obtained for three different types of copper tubes (smooth, corrugated and with micro-fins). Also, experimental data has been compared with theoretical data available. Correlations have been suggested for both pressure drop and Nusselt number for the three tube types [6] For heat transfer enhancement, the configuration of a shell-and-tube heat exchanger was improved through the installation of sealers in the shell-side. The results of heat transfer experiments show that the shell-side heat transfer coefficient of the improved heat exchanger increased by 18.2–25.5%, the overall coefficient of heat transfer increased by 15.6–19.7%, and the exergy efficiency increased by 12.9–14.1%. The heat transfer performance of the improved heat exchanger is intensified, which is an obvious benefit to the optimizing of heat exchanger design for energy conservation.[7] this paper proposed a simplified approach to optimize the design of Shell Tube Heat Exchanger [STHE] by flow induced vibration analysis [FVA]. The vibration analysis of STHE helps in achieving optimization in design by prevention of tube failure caused due to flow-induced vibration. The main reason for tube failure due to flow induced vibration is increased size of STHE. [8] investigated design Optimization of shell-and-tube heat exchanger by Differential Evolution (DE) method. For the optimal design of shell-and-tube heat exchangers improved version of Genetic Algorithm named Differential Evolution (DE) is used. Design variables: tube outer diameter, tube pitch, tube length, number of tube passes, no of shell, shell head type, shell layout, baffle spacing and baffle cut are taken for optimization. Bell's method is used to find the heat transfer area for a given design configuration. [9]

## 1.1. Literature review:

**In 2014 Jie Yang [10],** A constructal theory based optimization design method was proposed for heat exchanger design. In this work, a global heat exchanger is divided into several sub heat exchangers in series-and-parallel arrangement. The shell-and-tube heat exchanger is utilized for the method application, and design parameters considered was tube diameter, arrangement, thickness and number. The fitness function is the total cost of the shell-and-tube heat exchangers, including the investment cost for initial manufacture and the operational cost involving the power consumption to overcome the frictional pressure loss.

**In 2014, Chintan Patel et al. [11].**have planned Parameter optimization regarding shell and tube variety heat exchanger intended for improves the proficiency. It had been analysed by using taguchi process that has been placed on distinguish the key important variables which usually to be impacting this proficiency regarding shell and tube type heat exchanger. These parameters are generally tube diameter, mass flow rate and pitch length was used as input variable along with the output parameter was maximum temperature difference of shell and tube heat exchanger and CFX Computational fluid dynamics analysis was employed for Taguchi analysis. Essentially the most damaged parameter in temperature of water from tube diameter, pitch length and mass flow rate was found out from Taguchi analysis. Through the effects, this proficiency of shell and tube heat exchanger was improved.

**In 2015, Rihanna Khosraviet [12**] proposed the Shell and Tube Heat Exchanger (STHE) optimization to maximize thermal efficiency. Simulation results indicate that GA was unable to find permissible and optimal solutions in the majority of cases. Design variables found by FA and CS led

to maximum STHE efficiency. It is also found that the behaviour of the majority of decision variables remains consistent in different runs of the FA and CS optimization processes.

**Arzu Sencan Sahin et al. [13] 2011**, had proposed that Artificial Bee Colony (ABC) has been applied to minimize the total cost of the equipment including capital investment and the sum of discounted annual energy expenditures related to pumping of shell and tube heat exchanger by varying various design variables such as tube length, tube outer diameter, pitch size, baffle spacing, etc. The obtained results indicate that Artificial Bee Colony (ABC) algorithm can be successfully applied for optimal design of shell and tube heat exchangers. The algorithm proposed here can help the manufacturer and engineers to optimize heat exchangers in engineering applications.

**Gajanan P Nagre [14] 2016**, total heat flow rate, total annual cost and number of entropy production units of heat exchanges are optimized with specified mass flow rate under given space by multi-objective optimization. Paper shows effect of fin design parameters on the performance of plate-fin heat exchanges

**Axel groniewsky [15]2013,**thermodynamic evaluation is founded on the thermo economic optimization. Thermo economic techniques, in turn, are of two types such as the algebraic and calculus approaches. The algebraic techniques employ algebraic cost-balance equations obtained from traditional financial evaluation and supplementary cost equations for each subcomponent of any system offered. Calculus techniques, in essence, are constructed on differential equations

**Kiyarash Rahbar [16] 2015,**performed the optimization of the ORC based on two different types of heat exchangers to find the optimum heat transfer surface area and pressure drop. Results showed that, ORCs with the plate type heat exchangers have higher efficiencies compared to the ORCs with shell and tube

## 2. METHOD PROPOSED

The objective of this work is to predict energetic cycle efficiency for shell and tube heat exchanger by proposed Genetic Algorithm (GA) technique based on mathematical model. We proposed design constraints like tube configuration, different fluids, surface and temperature (fixed) as input parameters and these input parameters were implemented in mathematical modelling for evaluating energetic cycle efficiency of shell and tube heat exchangers. The work is implemented in MATLAB platform. The output of proposed method are analyzed and contrasted with actual dataset.

This proposed method turns out with minimum computational time and cost and shows good agreement with target data. The block diagram of proposed approach is depicted in fig. 1.

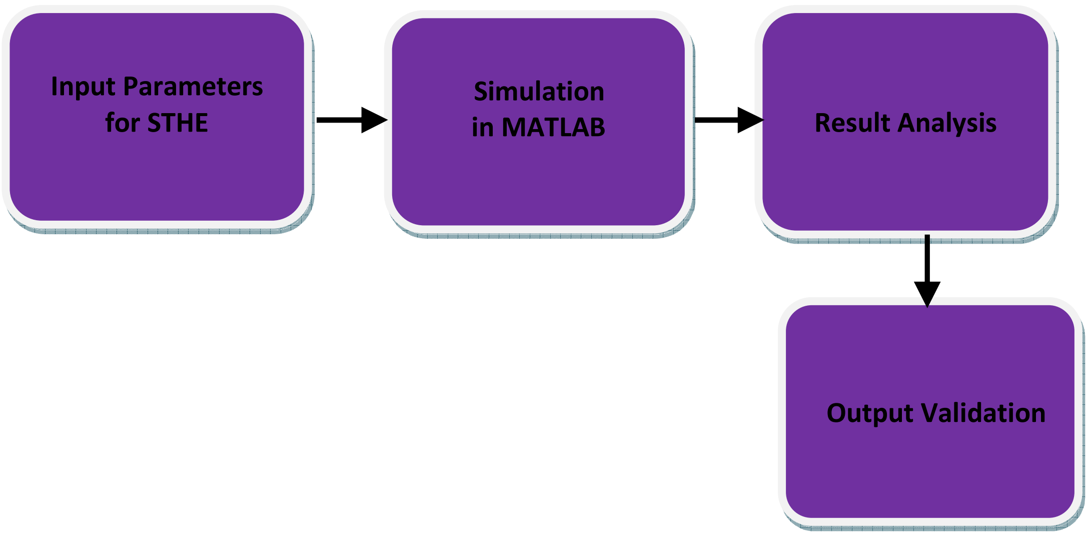


**Figure 1** Block Diagram for proposed Approach

## 3. MATHEMATICAL MODELLING

In this work we have considered a mathematical model to train the network with known input and output datasets to determine energetic cycle efficiency as output by proposed Genetic Algorithm (GA) method. The present mathematical model utilized four separate design constraints: tube configuration, fluids, surface and temperature (fixed) as input parameters and for each known input dataset the value of energetic cycle efficiency obtained as output of shell and tube heat exchangers (STHE). The mathematical modelling is presented by equation (1) [Roy. et.al, 2016]

$$M_i = \sum_{j=1}^{h} \alpha_i \frac{2}{\left[1 + \cosh \sum_{i=1}^{N} (S_i \beta_{ij}) - \exp \sum_{i=1}^{N} (S_i \beta_{ij})\right] - 1} \tag{1}$$

Where, i = Number of inputs, S = No of input parameters, α, β = Weights of parameters, j = Number of weights and h = Number of hidden neurons

Mathematical model was authenticated by Genetic algorithm (GA) to achieve optimal weight factors α and β of the system. Finally output results obtained from proposed method are contrasted with target dataset.

## 4. RESULT AND DISCUSSION

### 4.1 Iteration Graph

The convergence graph shown in fig.1 is graphical plot of fitness vs. iteration by proposed Genetic Algorithm (GA), where number of iterations is plotted along X-axis and fitness value along Y–axis. It has been observed that fitness stabilizes and achieved minimum value after maximum number of iterations.

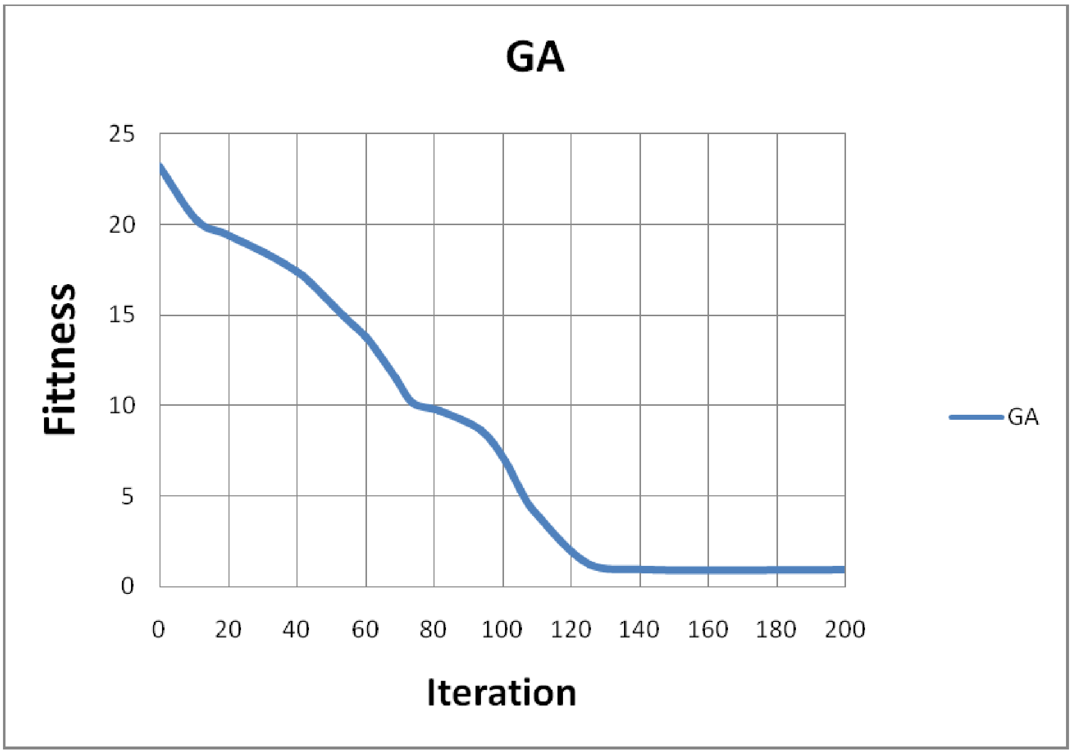


**Figure 2** Iteration Graph

## 4.2 Experimental results and expect values for proposed method

Table1 represents input and output parameters for testing data by proposed Genetic Algorithm (GA) and actual values found from experiments for shell and tube heat exchangers.

**Table 1** Estimated Results for testing data in GA

| ***Inputs*** | | | | ***Outputs*** | |
|---|---|---|---|---|---|
| **Tube Configuratio n** | **Different Fluids** | **Surface ($mm^2$)** | **Temperature ($^0C$)** | **Energetic Cycle Efficiency (%)** | |
| | | | | **Actual** | **Estimated by GA** |
| 30 | Isobutane | 1000 | 125 | 10.4 | 12.08 |
| 30 | R218 | 1000 | | 8 | 11.41 |
| 60 | Isobutane | 3000 | | 10.4 | 6.73 |
| 60 | R245 | 3000 | | 10.6 | 6.76 |
| 90 | R218 | 4000 | | 7.2 | 7.44 |
| 90 | R318 | 4000 | | 9.6 | 7.48 |

For 30 tube configuration, isobutene fluid energetic cycle efficiency determined by proposed GA approach is 12.08 and actual value is 10.4. So estimated energetic cycle efficiency by proposed method is increased by 16.15% of actual value. For 60 tube configuration with same fluid isobutene estimated cycle efficiency is 6.73 whereas actual value is 10.4. So estimated energetic cycle efficiency by proposed method is decreased by 35.29% of actual value. For 90- tube configuration with R-218 fluid estimated cycle efficiency is 7.44 whereas actual value is 7.2. So estimated energetic cycle efficiency by proposed method is increased by 3.33% of actual value. So, 90 & 60 tube configuration exhibits better performance by proposed method.

## 4.3 Shell and Tube configuration based Output parameters

This section shows the optimal tube configuration (30,60 and 90)for energetic cycle efficiency calculated based on input constraints.

The graphical plot shows that Energetic Cycle Efficiency shows consistent magnitude for 30, 60 and 90 tube configuration. The average value of Energetic Cycle efficiency observed around 10%. But for R-318 with 30 tube configuration a bid of slip of efficiency also found.

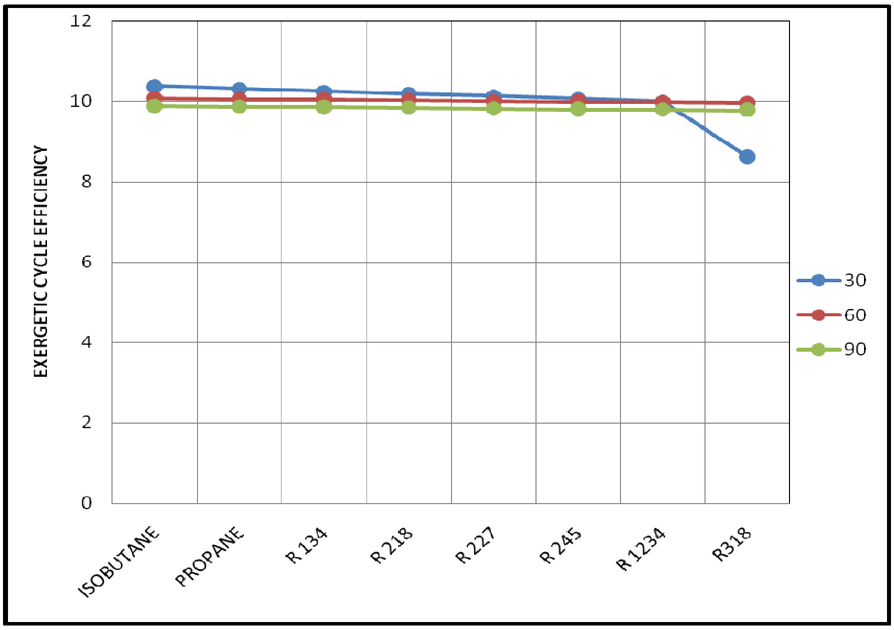


**Figure3** Energetic Cycle Efficiency

### 4.4 Comparative Analysis

In this section Fig 4 & Fig 5 shows comparative Graphical Plot for Energetic Cycle Efficiency for different Fluids and three different tube configurations (30, 60 & 90) for shell and tube heat exchanger.

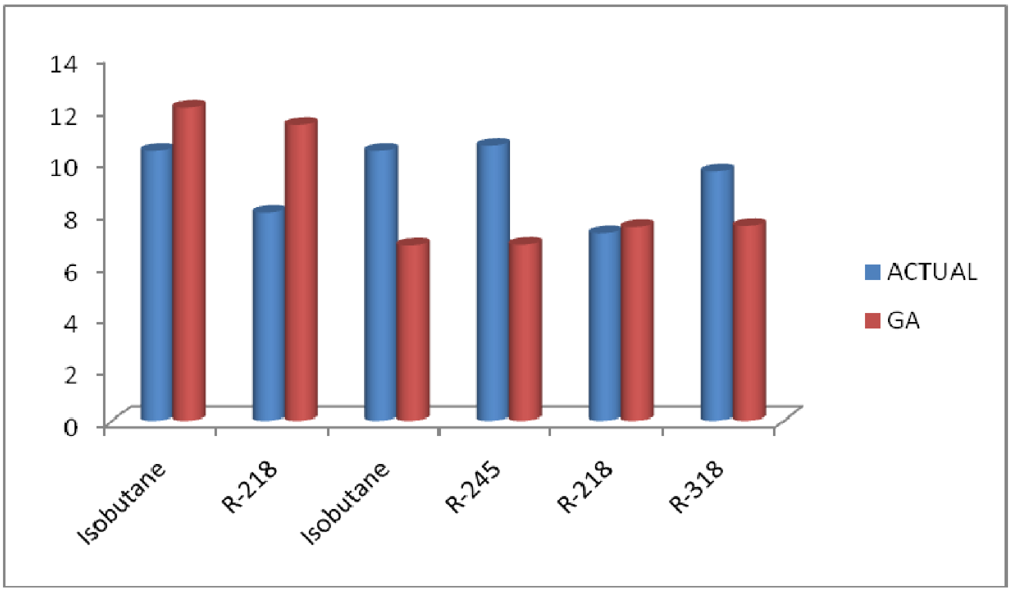


**Figure 4** Comparative Graphical Plot for Energetic Cycle Efficiency vs Fluid

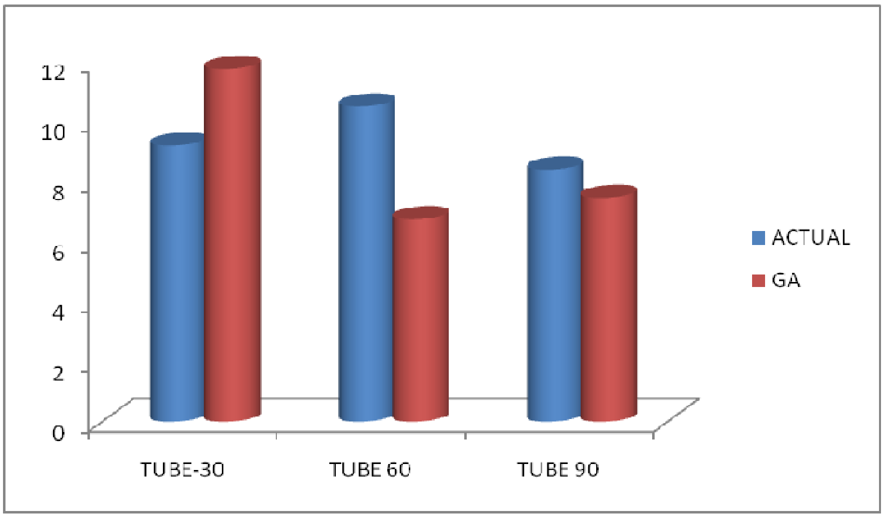


**Figure 5** Comparative Graphical Plot for energetic cycle efficiency vs Tube Configuration

Figure 4 shows that estimated cycle efficiency for R-218 is most nearest to the actual value in comparison with other fluids by proposed GA approach. Fig 5 illustrated that for 90 tube configuration estimated cycle efficiency shows better accuracy with actual value in comparison with other two tube configurations by proposed GA approach.

## 5. CONCLUSION

This paper considered three different tube configurations (30, 60 and 90) for STHE with known fluids, surface and temperature (Fixed) as input parameters to determine energetic cycle efficiency by proposed method. Energetic cycle efficiency obtained by proposed method are analyzed and contrasted with actual energetic cycle efficiency. It shows limited variation of output by proposed method compared with actual data. However, that best performance is achieved with 30 tube configuration with minimum slip-up from target dataset. So, it is best to use the 30-tube configuration if other input parameters remain constant to achieve appreciable accuracy in energetic cycle efficiency compared with actual data. Error validation graph for testing data demonstrated good agreement with proposed technique.

In future, more research on heat exchanger with novel techniques will lead excellent improvement in the performance parameters of the heat transfer process.

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## Author’s Biography:


**UTTAM ROY**

**Mr. Uttam Roy** completed his Bachelor of Mechanical Engineering from Jadavpur University, Kolkata in the year 2003 and Master of Engineering from Bengal Engineering and Science University Shibpur in the year 2005. He is working as a research scholar for PhD programme at National Institute of Technology Agartala since 2012.

He has more than ten years of Professional experience in reputed government and private organizations. He published more than eight papers in reputed international journals & two international books/monographs. He also filed two patents in his Mechanical Engineering Field. He is also associated with industry projects as an Engineer in R&D section.

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|  **MRINMOY MAJUMDER** | Dr. Mrinmoy Majumder completed his Bachelor of Electrical Engineering from Biju Patnaik University of Technology, Odissa in the year 2003. He completed Master of Engineering from Jadavpur Universityin the year 2006. Then he completed his PhD from Jadavpur University, Kolkatain the year 2010**.** Presently he is working as Assistant Professor at National Institute of Technology Agartala.<br>He has more than five years of teaching experience in national level government institution. He published more than forty papers in reputed international journals & ten international books. He has filed four patents in his field. He is also supervising research scholars at National Institute of Technology Agartala. |